

## TWO-HADRON SINGLE TARGET-SPIN ASYMMETRIES: FIRST MEASUREMENTS BY HERMES

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Single target-spin asymmetries in semi-inclusive two-pion production were measured for the first time by the HERMES experiment, using a longitudinally polarized deuterium target. These asymmetries relate to the unknown transversity distribution function  $h_1(x)$  through, also unknown, interference fragmentation functions. The presented results are compared with a model for the dependence of one of these interference fragmentation functions on the invariant mass of the pion pair.

### 1. Introduction

Of the three leading-twist quark distributions, the quark number density, the quark helicity and the quark transversity distribution, only the latter one is so far unmeasured. The main reason for this is its chiral-odd nature which requires a second chiral-odd object to couple to the transversity distribution in order to make it accessible to measurements. One candidate for such a chiral-odd fragmentation function is the so-called Collins fragmentation function appearing in pion lepton production. This has been studied by the HERMES experiment using a longitudinally polarized target<sup>1</sup>, and recently using a transversely polarized target<sup>2</sup>.

Another way of accessing transversity is offered by interference fragmentation functions, which appear in single target-spin asymmetries in two-pion semi-inclusive deep-inelastic scattering (DIS). One of the advantages of this method is that the azimuthal moment of the asymmetry is directly proportional to products of distribution and fragmentation functions, whereas in the case of one-hadron semi-inclusive DIS, these products are convoluted with the transverse momentum of the detected hadron. Although the interference fragmentation functions themselves are as yet unknown, they can be cleanly measured in  $e^+e^-$  experiments, such as Belle<sup>3</sup> and Babar.

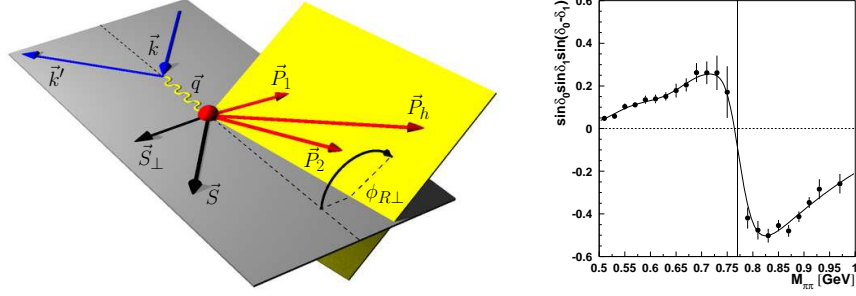


Figure 1. Left: kinematic planes, where  $\phi_{R\perp}$  is the angle between the plane spanned by the incident ( $\vec{k}$ ) and scattered lepton ( $\vec{k}'$ ) and the plane spanned by the two detected pions ( $\vec{P}_1$  and  $\vec{P}_2$ , with  $\vec{P}_h \equiv \vec{P}_1 + \vec{P}_2$ ). Right: the factor  $\sin \delta_0 \sin \delta_1 \sin(\delta_0 - \delta_1)$ , where the s- and p-wave phase shifts ( $\delta_0$  and  $\delta_1$ ) were obtained from pion-nucleon scattering experiments<sup>8</sup>. This factor shows the invariant mass dependent part of  $H_1^{\triangleleft,sp}$ , as predicted by Jaffe *et al.*<sup>5</sup>.

## 2. Single Spin Asymmetry

The transversity distribution can be accessed experimentally by measuring the single target-spin asymmetry, defined as:

$$A_{UL}(\phi_{R\perp}) = \frac{1}{|P_L|} \frac{N^{\rightarrow}(\phi_{R\perp})/N_d^{\rightarrow} - N^{\leftarrow}(\phi_{R\perp})/N_d^{\leftarrow}}{N^{\rightarrow}(\phi_{R\perp})/N_d^{\rightarrow} + N^{\leftarrow}(\phi_{R\perp})/N_d^{\leftarrow}} = \frac{\sigma_{UL}}{\sigma_{UU}}, \quad (1)$$

where  $N^{\rightarrow}$  ( $N^{\leftarrow}$ ) is the number of  $\pi^+\pi^-$  pairs detected with target spin antiparallel (parallel) to the direction of the beam momentum. These numbers are normalized to the corresponding number of DIS events,  $N_d^{\rightarrow}$  and  $N_d^{\leftarrow}$ , respectively and the entire ratio is divided by  $P_L$ , the longitudinal target polarization. The asymmetry is evaluated as a function of the azimuthal angle  $\phi_{R\perp}$ , which is shown in Fig. 1. In the last term,  $\sigma_{UL}$  and  $\sigma_{UU}$  are the polarized and unpolarized cross sections, respectively. According to Bacchetta *et al.*<sup>6</sup>  $\sigma_{UL}$  can be written at sub-leading twist as<sup>a</sup>:

$$\sigma_{UL} \sim \sum_q e_q^2 \sin \phi_{R\perp} \sin \theta [K_1 |\mathbf{S}_{\parallel}| h_L - K_2 |\mathbf{S}_{\perp}| h_1] (H_1^{\triangleleft,sp} + H_1^{\triangleleft,pp} \cos \theta), \quad (2)$$

where  $K_1$  and  $K_2$  are kinematic factors<sup>b</sup> and  $\theta$  is the angle between the direction of emission of the pion pair in its center-of-mass frame and  $\vec{P}_h$  in the hadronic frame (see Fig. 1). Eq. 2 introduces the two-hadron interference

<sup>a</sup>Eq. 2 was derived using the Wandzura-Wilczek approximation and is valid at low invariant mass  $M_{\pi\pi}$  of the pion pair

<sup>b</sup>See the article by Bacchetta *et al.*<sup>6</sup> for the full expression.

fragmentation functions  $H_1^{\triangleleft,sp}$  and  $H_1^{\triangleleft,pp}$ . They describe the interference between different production channels of the pion pair:  $H_1^{\triangleleft,sp}$  relates to the interference between s- and p-wave states and  $H_1^{\triangleleft,pp}$  to the interference between two p-wave states. Both functions can be used *separately* to extract information on the transversity distribution  $h_1(x)$ . In the present analysis the  $\sin \phi_{R\perp}$ -moment of the asymmetry,  $A_{UL}^{\sin \phi_{R\perp}}$  has been studied, which is only sensitive to  $H_1^{\triangleleft,sp}$ , because in evaluating  $A_{UL}^{\sin \phi_{R\perp}}$  the integral is taken over the polar angle  $\theta$ .

A prediction was given by Jaffe *et al.*<sup>5</sup> for the invariant-mass behavior of  $H_1^{\triangleleft,sp}$  in terms of s- and p-wave phase shifts. Fig. 1 shows that according to this model the asymmetry would change sign approximately at the  $\rho^0$  mass. Note, however, that this model does not predict the size or sign of the asymmetry.

Two distribution functions appear in Eq. 2: the transversity distribution  $h_1$  and the subleading-twist function  $h_L$ , which is related to  $h_1$  through a Wandzura-Wilzcek relation. The contribution of these functions is proportional to the target polarization components transverse ( $\mathbf{S}_\perp$ ) and parallel ( $\mathbf{S}_\parallel$ ) to the virtual photon direction, respectively. In the data presented here the value of  $\mathbf{S}_\perp$  increases from 3% of  $\mathbf{S}_\parallel$  at low  $x$  to 9% at high  $x$ . For the present analysis data were taken during the period 1998-2000 with a longitudinally polarized deuterium (gas) target. The average target polarization was  $0.84 \pm 0.04$ .

### 3. Results

In Fig. 2 the  $\sin \phi_{R\perp}$ -moment<sup>c</sup>  $A_{UL}^{\sin \phi_{R\perp}}$  is plotted versus the invariant mass of the pion pair<sup>d</sup>  $M_{\pi\pi}$  in panels of increasing  $x$  ( $= Q^2/(2M\nu)$ ) and  $z$  ( $z \equiv E_{\pi\pi}/\nu$ ). The size of the asymmetries is on the order of a few percent. For all panels the asymmetries are not inconsistent with zero given the size of the statistical errors. No significant  $x$ - or  $z$ -dependence is observed. The shape of the asymmetries versus the invariant mass has been compared with the model prediction shown in Fig. 1. This was done by fitting the following function to the data:

$$f(M_{\pi\pi}) = c_1 \mathcal{P}(M_{\pi\pi}) + c_2 \quad (3)$$

<sup>c</sup>Using the definition of  $\phi_{R\perp}$  shown in Fig. 1,  $A_{UL}^{\sin \phi_{R\perp}}$  will differ by a sign, compared with the situation where the azimuthal angle is defined according to the Trento conventions<sup>4</sup>.

<sup>d</sup>For these preliminary results, all hadron types were analyzed assuming they were pions. The corresponding uncertainty is not included in the quoted systematic error.

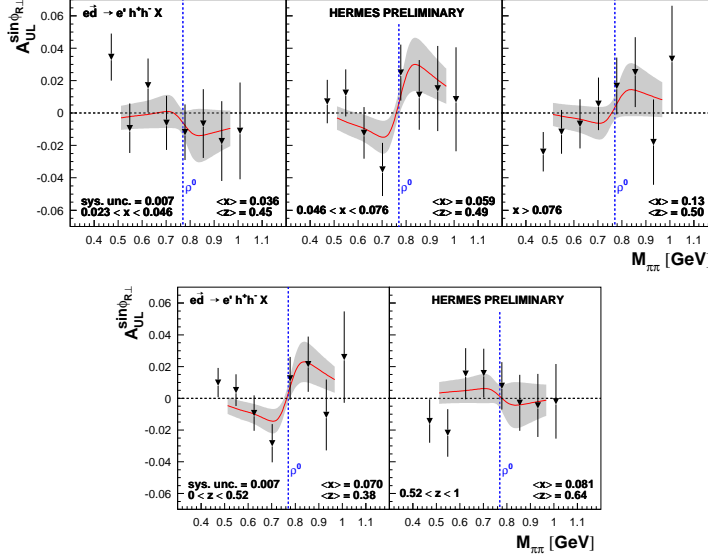


Figure 2. The asymmetry-moment  $A_{UL}^{\sin \phi_{RL}}$  as a function of the invariant mass  $M_{\pi\pi}$  for different  $x$ -bins (top) and  $z$ -bins (bottom).

where  $\mathcal{P}(M_{\pi\pi})$  contains the invariant-mass dependence from the model prediction and  $c_1$  and  $c_2$  are free parameters of the fit. The resulting curves are included in Fig. 2. These curves show that in all panels, the results are consistent with the model. In the mid- $x$  and low- $z$  region the data give a hint for a sign change of the asymmetry at the  $\rho^0$  mass.

Starting in 2002, HERMES has been taking data with a transversely polarized hydrogen target, with an average polarization of  $0.78 \pm 0.04$ , which can result in much larger asymmetries. Data-taking will continue until the summer of 2005. The analysis of these data is ongoing and first results are expected in the near future.

## References

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